LEVEL III

Research and Development Technical Report

DELET-TR-78-3015-2

3.2 MILLIMETER WAVE TRANSMITTER TUBE

J. A. Davis
Hughes Aircraft Company
Electron Dynamics Division
3100 West Lomita Boulevard
Torrance, California 90509

MARCH 1980

Second Interim Report for Period 1 February 1979 - 31 May 1979

DTIC
APR 1 : 1980

E

Prepared for:
Electronics Technology & Devices Laboratory

ERADCOM

US ARMY ELECTRONICS RESEARCH AND DEVELOPMENT COMMAND
FORT MONMOUTH, NEW JERSEY 07703

NOTICES

Disclaimers

The citation of trade names and names of manufacturers in
this report is not to be construed as official Government
indorsement or approval of commercial products or services
referenced herein.

Disposition

Destroy this report when it is no longer needed. Do not
return it to the originator.

REPORT DOCUMENTATION PAGE		READ INSTRUCTIONS BEFORE COMPLETING FORM
1. REPORT NUMBER DELET TR-78-3015-2	2. GOVT ACCESSION NO.	3. RECIPIENT'S CATALOG NUMBER
4. TITLE (and Subtitle) 3.2 Millimeter Wave Transmitter Tube		5. TYPE OF REPORT & PERIOD COVERED Second Interim 1 Feb 79 — 31 May 79 6. PERFORMING ORG. REPORT NUMBER
7. AUTHOR(s) J. A. Davis		8. CONTRACT OR GRANT NUMBER(s) DAAB07-78-C-3015
9. PERFORMING ORGANIZATION NAME AND ADDRESS Hughes Aircraft Company, Electron Dynamics Div 3100 West Lomita Blvd Torrance, CA 90509		10. PROGRAM ELEMENT, PROJECT, TASK AREA & WORK UNIT NUMBERS 62705A 1L1 62705 AH94 01 02
11. CONTROLLING OFFICE NAME AND ADDRESS ET&D Laboratory (ERADCOM) ATTN: DELET-BM Fort Monmouth, NJ 07703		12. REPORT DATE March 1980 13. NUMBER OF PAGES 16
14. MONITORING AGENCY NAME & ADDRESS(if different from Controlling Office)		15. SECURITY CLASS. (of this report) UNCLASSIFIED
		15a. DECLASSIFICATION DOWNGRADING SCHEDULE

16. DISTRIBUTION STATEMENT (of this Report)

Approved for public release;
Distribution Unlimited.

17. DISTRIBUTION STATEMENT (of the abstract entered in Block 20, if different from Report)

18. SUPPLEMENTARY NOTES

19. KEY WORDS (Continue on reverse side if necessary and identify by block number)

Millimeter Wave
Pulse Amplifier
Coupled Cavity Traveling Wave Tube

20. ABSTRACT (Continue on reverse side if necessary and identify by block number)

Considerable progress has been made in the design of the 100 W peak
(50 W avg.) power TWT, designated the 982H. The basic rf circuit has been
tentatively designed, subject to further evaluation by testing with scaled
x-band parts. The windows, taper (transformer), collector, and magnets have
been designed. The electrical design of the gun is nearly complete, and
the mechanical layout must still be prepared.

DD FORM 1473
1 JAN 73

TABLE OF CONTENTS

LIST OF ILLUSTRATIONS

1. INTRODUCTION

The objective of this program is the development of 3.2 millimeter wave
tubes having the smallest possible volume, lowest possible weight, and
the lowest potential production cost without compromise of performance.
The tube objectives are:

Peak RF power output	1 kW (maximum)
	100 W (minimum)
Average RF power	50 W (liquid cooled)
	Concurrent with 100 W peak
	10 W (air cooled)
	Concurrent with 1 kW peak
Center frequency	93.75 GHz
Instantaneous bandwidth	2 GHz
Small signal gain	60 dB
Large signal gain	50 dB
Pulse length	25 μs max, 1-10 ns objective
Pulse rise time	1 μs
PRF	20 KHz max
Length	approx 61 cm
Width	10 cm
Height	10 cm
Weight	7 kg

The program consists of two parallel phases, the first being concerned
with the 100 W TWT and the second with the 1 kW TWT.

Considerable progress has been made in the design of the 100W peak
(50W avg.) power TWT, designated the 982H. The basic rf circuit has
been tentatively designed, subject to further evaluation by testing with
scaled X-band parts. The windows, taper (transformer), collector, and

1

magnets have been designed. The electrical design of the gun is nearly complete, and the mechanical layout must still be prepared.

A thicker (0.020") vacuum sheath will be used on this tube, rather than the normal 0.005" thick sheath which has been used on most Hughes EDD mm-wave TWT's to date. The thicker sheath will give greater structural stability to the circuit. Also, the magnetic pole pieces will be brazed directly to this sheath, creating precise and secure alignment of the magnets to the rf circuit.

2. RF CIRCUIT DESIGN

The tentaive RF circuit design is shown in Figure 1, along with the scaled X-band parameters. The computer predicted dispersion curve is shown in Figure 2. The center frequency of the hot band interacts with the beam at a value of $\beta L/\pi = 1.42$. Because of the magnetic focusing constraints, a relatively large beam hole of 0.019" has been chosen, giving a relatively large δ a of 1.65.

The scaled X-band parts have been ordered. The circuit will be cold matched at X-band, when the final values of ferrule gaps and aperture angles will be determined. At W-band there will be adjustable ferrules and backwalls in the match cavities, so that fine tuning of individual circuits will be possible. Also at W-band, a selection of termination ceramics with different slopes will be available. To optimize the cold reflection match.

G6619
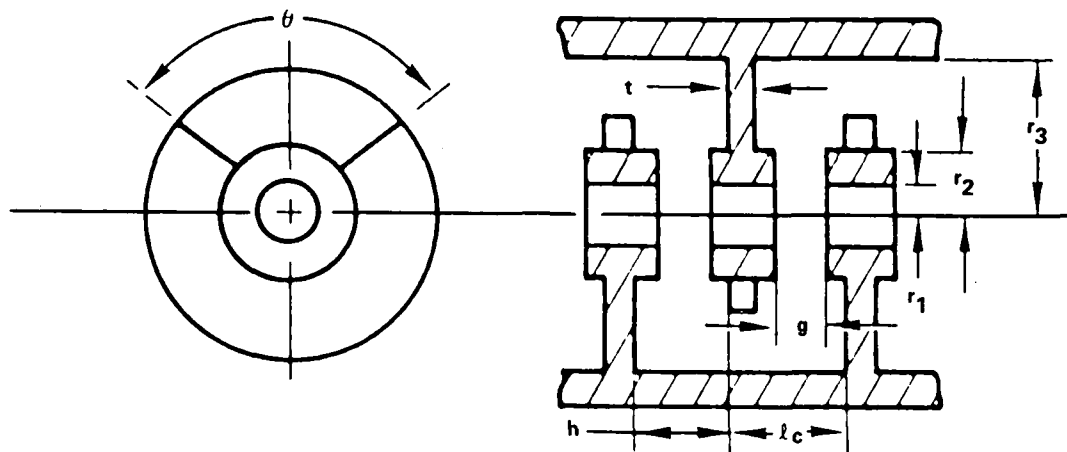
	W-BAND	$\left[\text{SCALE FACTOR: } \dfrac{0.900}{0.100} = 9.00 \right]$	X-BAND
$2r_1$	0.019 INCHES		0.171 INCHES
$2r_2$	0.030		0.270
$2r_3$	0.06276		0.56484
θ	125°		125°
l_c	0.0247		0.2223
h	0.0177		0.1593
t	0.007		0.063
g	0.00987		0.089
CIRCUIT O.D.	0.170		

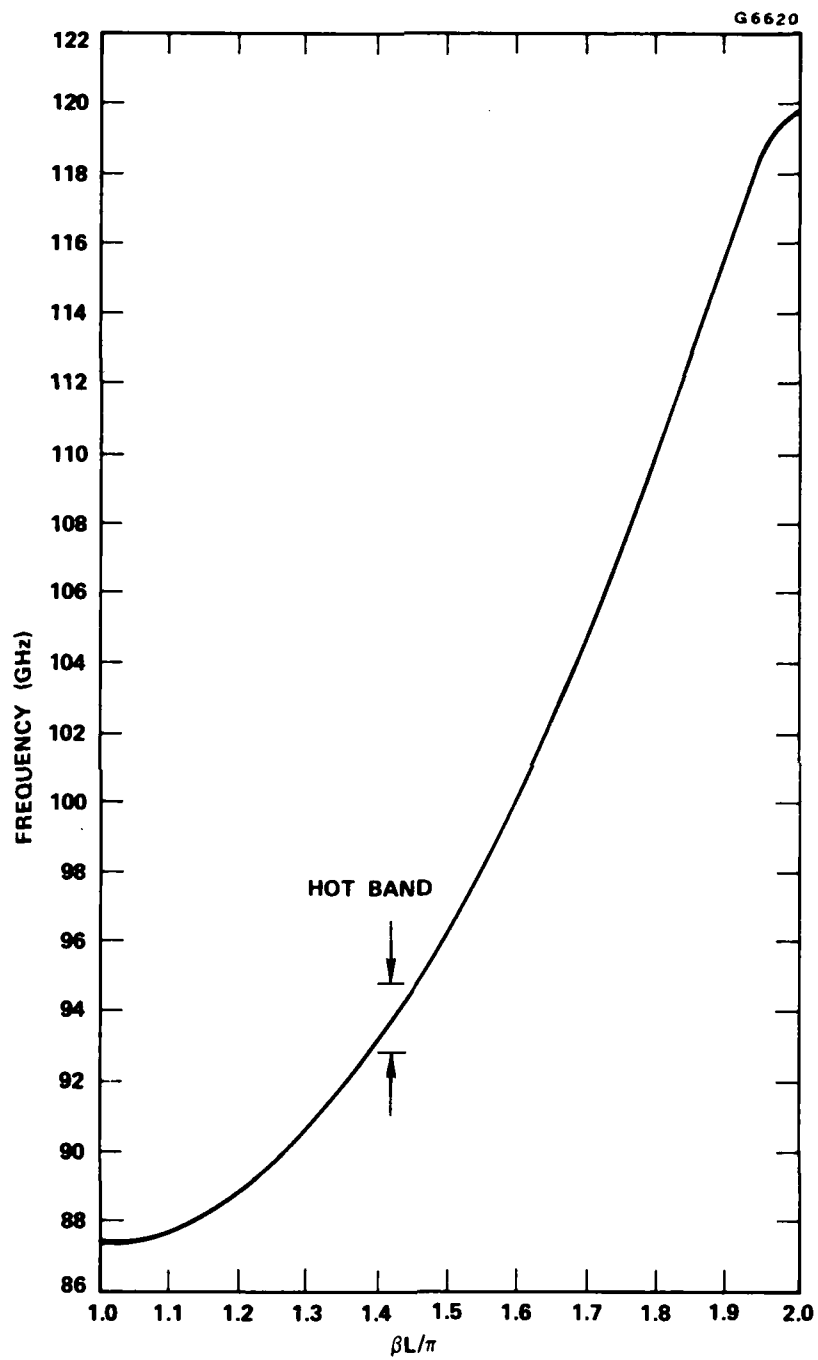FIGURE 1   TENTATIVE CAVITY DESIGN

4

FIGURE 2. DISPERSION CHARACTERISTIC

3. MAGNET DESIGN

The periodic permanent magnet (PPM) design is constrained by 1) the
magnetic field magnitude as predicted by the Ambose computer program,
which predicts the beam focusing of the electron gun with the periodic
magnet structure 2) the scallop wavelength, determined also by the
Ambose program in which the ratio of scallop wavelength to magnetic
period must be greater than 1.2, 3) the minimum pole piece I.D., which
must be larger than the vacuum sheath O.D., 4) the constraint that the
iron pole pieces must not be saturated, and 5) the fact that the trans-
formers both take up room that cannot be filled by magnets and the resul-
ting magnetic void allows leakage flux which further substracts from the
axial field available at the coupler location.

Samarium cobalt magnets will be used, since they deliver the greatest
magnetic field per unit volume of any readily available material.

Vacuum melted electrolytic iron pole pieces will be used, rather than
cold rolled steel, because iron saturates at about a 2 kilo-Gauss
higher field.

The basic magnet design is shown in Figure 3. The iron pole pieces are
brazed directly onto the 0.020" thick vacuum sheath. The pole pieces
are ferruleless, which allows for a simpler pole piece design at no
sacrifice in magnetic field. The pole pieces are of a smaller O.D. than
the magnets, because it has been empirically shown on other tubes that
we get a greater field on axis than if the pole pieces and magnets are
of the same diameter, presumably because of a reduction in the fringing
flux at the O.D. The Amboss program predicts a scallop wavelength of
0.60 and the magnetic period chosen is 0.436.

The gun and collector pole pieces are made of iron to magnetically shield
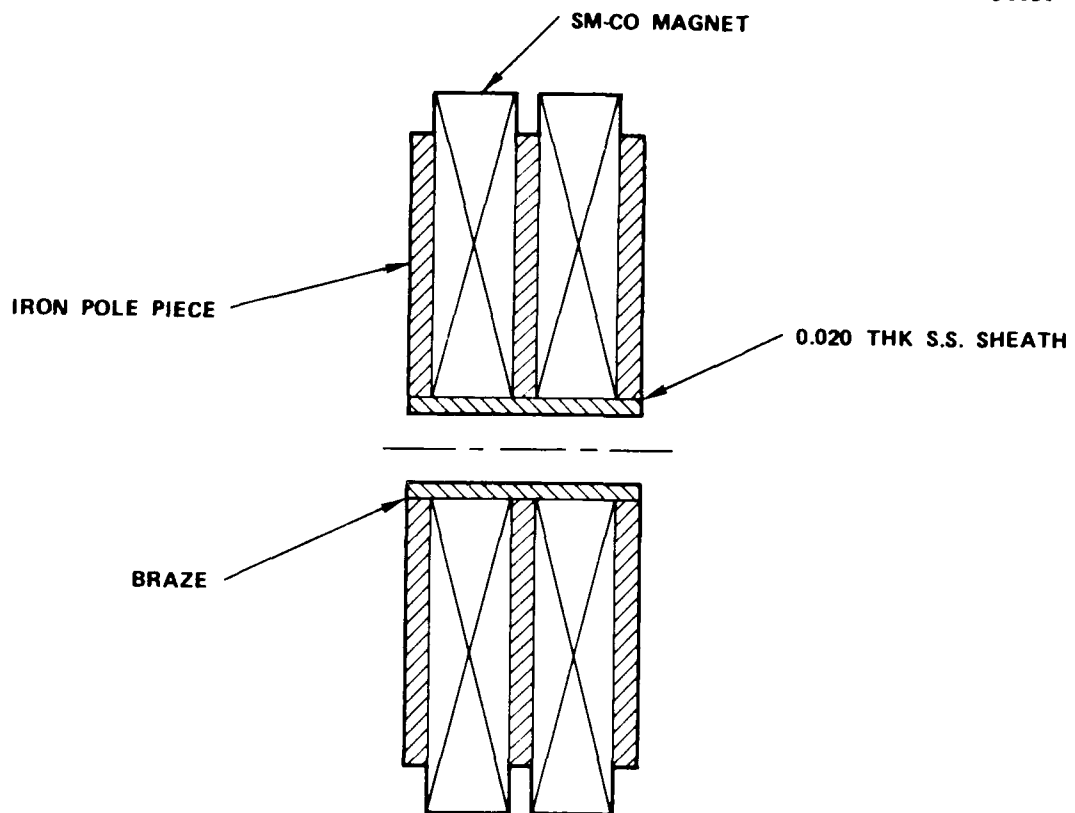the gun and collector. Because these pole pieces are of greater diameter

G6621

SM-CO MAGNET

IRON POLE PIECE

0.020 THK S.S. SHEATH

BRAZE

FIGURE 3   MAGNET DESIGN

7

than the other pole pieces, the fringing flux at the O.D. is greater than normal, and it is necessary to increase the thickness and perhaps the diameters of the magnets at the ends. In order to keep the magnetic period constant, ferrules will be put on both the gun and collector pole pieces. A computer program has been written to calculate the magnet thickness required.

Because this tube has a beam scraper, the input transformer (actually a taper) is not adjacent to the gun pole piece. Since it is desirable to keep the magnetic period constant, it is not possible to make the magnets at the input transformer thicker to compensate for the reduction in magnet volume and the additional fringing flux through the transformer. The magnet diameter can be increased, if necessary. It is our intention to experiment with the beam tester to determine the magnet diameter and pole piece thickness required in this region, using different iron shims and different diameters and thickness magnets. A larger diameter magnet than standard complicates the package design, especially cooling design, so an unnecessarily large diameter should be avoided if possible. However, a computer program has been written to calculate the fields necessary, and it shows that the standard 1.5 inch diameter magnet would be adequate.

4. WINDOW DESIGN

A block window with beryllia ceramic will be used on the TWT. The beryllia will be metallized and brazed into elkonite, which matches the thermal expansion of the beryllia.

Irises with circular holes are spaced symmetrically on each side of the ceramic block. The spacers between the ceramic and iris are also elkonite, to minimize distortion during braze.

The ceramic thickness, iris size and iris to block spacing were determined from a computer program which calculates the reflectance, given the window parameters. This program has recently been rewritten to loop, so as to automatically design a window whose reflection closely matches the magnitude of a third order Chelyshev polynomial. This is accomplished by having the computer minimize the sum of the reflections at the calculated three Chelyshev zeroes, by varying the block thickness, iris separation and iris opening.

Figure 4 shows a plot of the theoretical percent reflectance versus frequency. It is not possible to get a good match over the entire cold band (87.3 to 119.3 GHz), but the region from just above lower cut-off to 106 GHz has a reflectance of no more than 2.7%. The rf circuit has sufficient loss from the skin effect that no oscillation problems are expected, even at the frequencies where the window is not a good match.
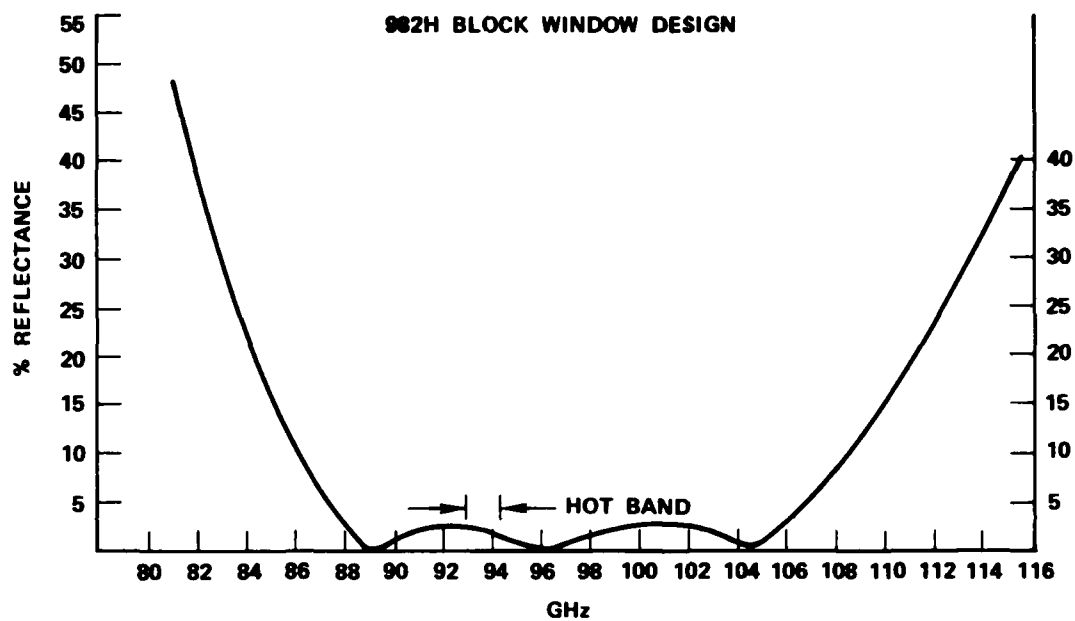
982H BLOCK WINDOW DESIGN

FIGURE 4   WINDOW REFLECTANCE

5. ELECTRON GUN

The electron gun design is currently in progress. An aperture grid is
to be added to the electrical design. The beam diameter versus distance
for the gun without aperture grid is shown in Figure 5. 99.5% of the
beam current is within the dotted line ($R_{99.5}$) and 95% of the current is
within the solid line (R_{95}). One would therefore expect about 98.5%
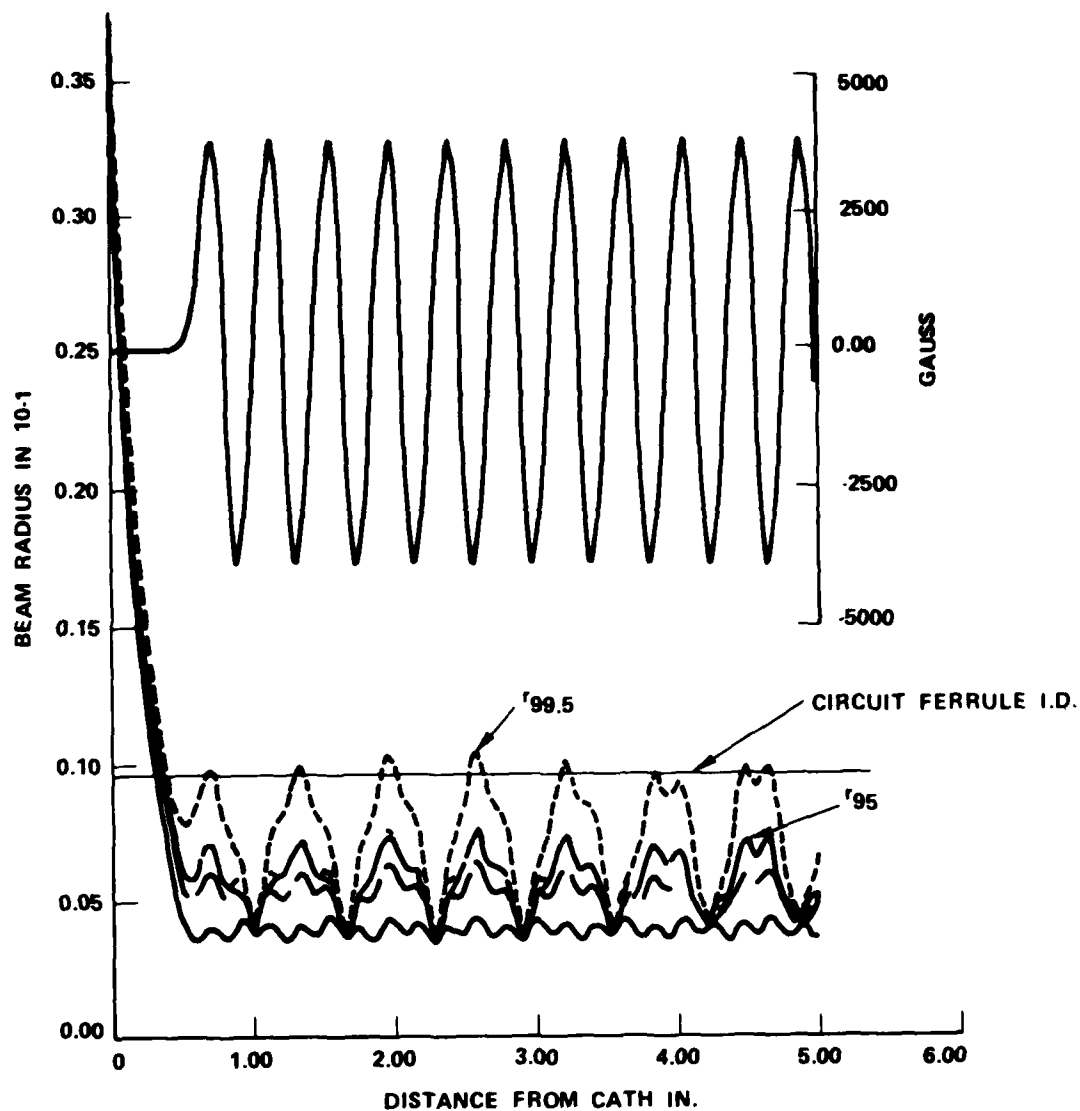transmission during d.c. operation.

FIGURE 5. AMBOSS COMPUTER PROGRAM TO OPTIMIZE THE
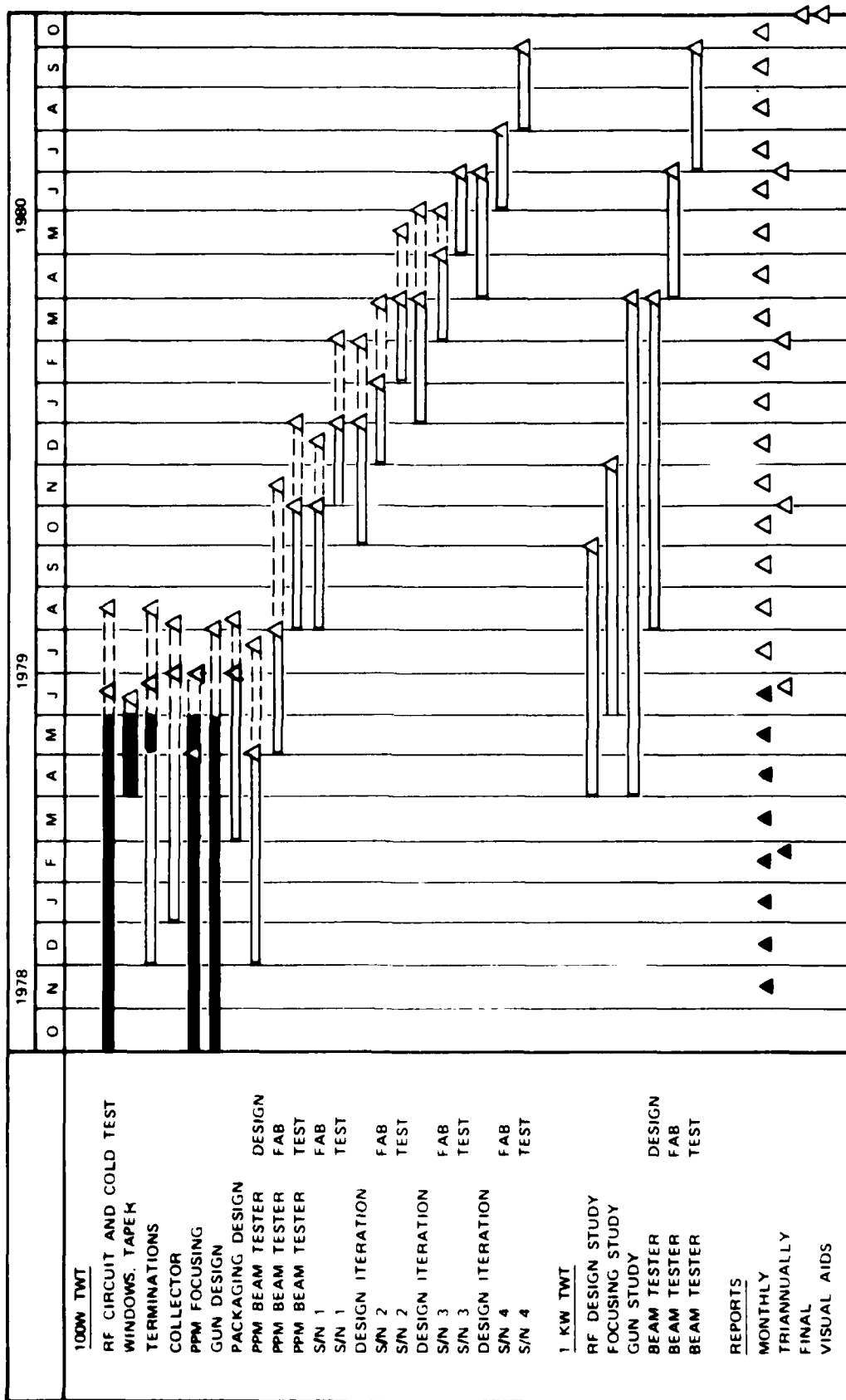THERMAL BEAM GEOMETRY AND FOCUSING.

6. TAPERS

Instead of stepped transformers, tapers will be used. Tapers should be broader band, less susceptible to dimensional changes, and more economical to manufacture.

7. COLLECTOR

The collector will be a refinement of an existing design. It has a
beryllia ceramic for voltage standoff, and is of such a design that the
original liquid cooled version can later be modified to air cooling with
only minor changes.

8.   PROGRAM SCHEDULE

PROGRAM SCHEDULE

	1978			1979										1980							
	O	N	D	J	F	M	A	M	J	J	A	S	O	N	D	J	F	M	A	M	J	J	A	S	O

100W TWT
RF CIRCUIT AND COLD TEST
WINDOWS, TAPER
TERMINATIONS
COLLECTOR
PPM FOCUSING
GUN DESIGN
PACKAGING DESIGN   DESIGN
PPM BEAM TESTER   FAB
PPM BEAM TESTER   TEST
PPM BEAM TESTER   FAB
S/N 1   TEST
S/N 1
DESIGN ITERATION
S/N 2   FAB
S/N 2   TEST
DESIGN ITERATION
S/N 3   FAB
S/N 3   TEST
DESIGN ITERATION
S/N 4   FAB
S/N 4   TEST

1 KW TWT
RF DESIGN STUDY
FOCUSING STUDY
GUN STUDY   DESIGN
BEAM TESTER   FAB
BEAM TESTER   TEST
BEAM TESTER

REPORTS
MONTHLY
TRIANNUALLY
FINAL
VISUAL AIDS

16

ELECTRONICS TECHNOLOGY AND DEVICES LABORATORY

DISTRIBUTION LIST

1 June 1979

101	DEFENSE DOCUMENTATION CENTER ATTN: DDC-TCA CAMERON STATION (BLDG 5)	481	HARRY DIAMOND LABORATORIES, DA ATTN: DELHD-RCB (R. J. NEMARICH) 2800 POWDER MILL ROAD	
012	ALEXANDRIA, VA 22314			
		001	ADELPHI, MD 20783	
104	DEFENSE COMMUNICATIONS AGENCY TECHNICAL LIBRARY CENTER CODE 205 (P. A. TOLOVI)	483	DIRECTOR US ARMY MATERIAL SYSTEMS ANALYSIS ACTV	
001	WASHINGTON, DC 20305		ATTN: DRXSY MP	
200	OFFICE OF NAVAL RESEARCH CODE 427	001	ABERDEEN PROVING GROUND, MD 21005	
001	ARLINGTON, VA 22217	680	COMMANDER	
			US ARMY ELECTRONICS R&D COMMAND	
205	DIRECTOR	000	FORT MONMOUTH, NJ 07703	
	NAVAL RESEARCH LABORATORY ATTN: CODE 2627			
001	WASHINGTON, DC 20375		1	DRDEL-SA
			1	DELEW-D
			3	DELCS-D
301	ROME AIR DEVELOPMENT CENTER ATTN: DOCUMENTS LIBRARY (TILD)			
001	GRIFFISS AFB, NY 13441		1	DELET-D
			1	DELET-DD
			2	DELET-DT
407	DIRECTOR, BALLISTIC MISSILE		5	DELET-
	DEFENSE ADVANCED TECHNOLOGY		1	DELSD-D
	CENTER		1	DELSD-AS
	ATTN: ATC-R, PO BOX 1500		1	DELSD-L (TECH LIB)
001	HUNTSVILLE, AL 35807		2	DELSD-L-S (STINFO)
			25	DELET-TL-B (FISCHER)
437	DEPUTY FOR SCIENCE & TECHNOLOGY OFFICE, ASSIST SEC ARMY (R&D)	705	ADVISORY GROUP ON ELECTRON DEVICES	
001	WASHINGTON, DC 20310		201 VARICK STREET, 9TH FLOOR	
475	CDR. HARRY DIAMOND LABORATORIES ATTN: LIBRARY 2800 POWDER MILL ROAD	002	NEW YORK, NY 10014	
001	ADELPHI, MD 20783		OFFICE OF DEPUTY CHIEF OF STAFF FOR RESEARCH DEVELOPMENT & ACQUISITION	
477	DIRECTOR US ARMY BALLISTIC RESEARCH LABS ATTN: DRXBR-LB		ATTN: DAMA-Z-E (DR. CHARLES CHURCH)	
		001	ADVANCED CONCEPTS TEAM	
001	ABERDENN PROVING GROUND, MD 21005		WASHINGTON, D. C. 20310	

MR. GERRY KOOYERS
UNIVERSAL COMPUTER APPLICATIONS
701 WELCH ROAD
PALO ALTO, CA 94304

COMMANDER
NAVAL OCEAN SYSTEMS COMMAND
ATTN: R. WILLS, CODE 8212
271 CATALINA BLVD.
001 SAN DIEGO, CA 92152

DR. PAUL COLEMAN
UNIVERSITY OF ILLINOIS
001 URBANA, ILLINOIS

DR. RICHARD GROW
UNIVERSITY OF UTAH
ELECTRICAL ENGINEERING DEPT.
001 SALT LAKE CITY, UT